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Enhancing stoichiometry learning through youtube video-lists

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ABSTRACT

Stoichiometry is generally seen by students as one of the most difficult subjects to understand. This has been observed through our experience as high school teachers in public and private schools in Brazil. We have realized that new teaching resources are needed to minimize such difficulties, assisting both the teaching and learning process. Teaching materials produced by teachers themselves must be more efficient, as they portray the school reality itself, making teaching, in a certain way, personalized. In addition, these classroom materials must be made available online in order to serve the largest possible number of students. This work involves the creation of an educational product, presented as an audiovisual resource, as it brings very efficient elements to the teaching and learning process, such as movement, colors and sounds. In the Programa de Mestrado Profissional em Química em Rede Nacional (PROFQUI) of the Universidade Federal do Rio Grande do Sul (UFRGS), we created a YouTube channel, which presents the solution of stoichiometry exercises of increasing difficulty level. The videos were recorded on a smartphone and edited using free software, in a process that can be reproduced by any teacher with internet access. Thus, our work mainly aims to develop such materials to serve as inspiration for teachers to create their own classroom materials, based on the school reality in which they are inserted. Questionnaires were applied before and after the use of the material and the data collected were analyzed from the perspective of Bardin's content analysis. The material presented excellent results in terms of improving the learning of stoichiometry, results verified through a pre- and post-test, as well as a questionnaire on the students' impression of the material produced.

KEYWORDS: Chemistry teaching; Stoichiometry; Audiovisual resources.

Aprimorando a aprendizagem em estequiometria por meio de vídeo-lista no youtube

RESUMO

Estequiometria é geralmente visto pelos estudantes como um dos assuntos mais difíceis de entender. Isso pôde ser observado por meio de nossa experiência como professores do ensino médio, em escolas públicas e privadas, no Brasil. Percebemos que novos recursos didáticos são necessários para minimizar tais dificuldades, auxiliando tanto no processo de ensino quanto na aprendizagem. Os materiais didáticos produzidos pelos próprios professores devem ser mais eficientes, pois retratam a própria realidade escolar, tornando o ensino, de certa forma, personalizado. Além disso, esses materiais de sala de aula devem ser disponibilizados on-line, a fim de atender o maior número possível de estudantes. Este trabalho envolve a criação de um produto educacional, apresentado como um recurso audiovisual, pois traz elementos muito eficientes no processo de ensino e aprendizagem, como movimento, cores e sons. No Programa de Mestrado Profissional em Química em Rede Nacional (PROFQUI) da Universidade Federal do Rio Grande do Sul (UFRGS), criamos um canal no YouTube, que apresenta a solução de exercícios de estequiometria de nível de dificuldade crescente. Os vídeos foram gravados em smartphone e editados em software livre, em processo que pode ser reproduzido por qualquer professor que tenha acesso à internet. Dessa forma, nosso trabalho visa principalmente desenvolver tais materiais para servir de inspiração para que os professores criem seus próprios materiais de sala de aula, baseados na realidade escolar em que estão inseridos. Foram aplicados questionários antes e após a utilização do material e os dados coletados foram analisados sob a perspectiva da análise de conteúdo de Bardin. O material apresentou ótimos resultados no sentido de melhorar o aprendizado da estequiometria, os quais foram verificados por meio de um pré e um pós-teste, bem como, por meio de pós-questionário que avaliou a impressão dos estudantes sobre o material produzido.

PALAVRAS-CHAVE: Ensino de Química; Estequiometria; Recursos Audiovisuais.

Introduction

The importance of stoichiometry for learning chemistry can be defended from an integrative perspective, considering that this topic is strongly related to the other content of the discipline and has its applications in different contexts (Cirilo & Colagrande, 2023). High school and college students consider the concepts of stoichiometry as complex and difficult (Sousa Silva, Bertini & Alves, 2018). In addition, a series of prerequisites are necessary for interpreting problems (Le Marie et al., 2018). Such difficulties are related to the need for mastery of mathematical, physical, and chemical languages, as well as reading comprehension when solving problems involving stoichiometric calculations (Raupp, Haupt, Bentlin, Gomes & Rockenbach, 2023). Thus, in the classroom, there is a demand to dedicate time to reviewing these concepts, time that could be dedicated to problem solving (Fernandes, 2019). As a result, there are a large number of students with poor performance in solving stoichiometric problems, since it is necessary to solve a series of subproblems such as empirical formulas, mass percentage or chemical balancing equations (Rosa, Corrales, Nguyen & Atkinson, 2022). Moreover, for this reason; Gulacar Gulacar, Overton, Bowman & Fynewever (2013) went so far as to state that it has been a thorn in the side of students and teachers since its introduction; students struggling to learn the subject and teachers struggling to teach it in the best possible way. The teaching of stoichiometry faces numerous problems in both basic and higher education, ranging from the lack of preparation of teachers in implementing pedagogical practices that can lead students to understand the abstract concepts involved to the difficulty in mathematical calculations by students. Therefore, it is urgent to create methodologies that aim to resolve the difficulties presented, so that it is possible to facilitate the learning process and make the study of this content less traumatic. Many teaching strategies have been designed with the aim of obtaining better results. These strategies have in common the attempt to overcome the existing barrier to mathematical thinking and, from there, to make the time dedicated to classes focused on the understanding of stoichiometric concepts. For example, creating algorithms, instructional activities guided by spreadsheets and graphs, use of media, digital resources and games (Fernandes, 2019; Gulacar, Mann, Mann & Vernoy, 2022).

With the aim of understanding the difficulties in learning stoichiometric concepts, and developing an educational product to contribute to overcoming such difficulties, this work presents an educational product developed as part of the research of the Programa de Mestrado Profissional em Química em Rede Nacional (PROFQUI). The analysis of the application of the teaching strategy developed in the form of a Video-list is presented as a case study carried out with high school students from a school in the metropolitan region of Porto Alegre.

Digital technologies and the educational context

The digital revolution has triggered many developments and innovations in various fields. We currently have students from the so-called Generation Z (GenZ) in our classrooms. Born with almost infinite connectivity, GenZ is very active on the internet (Persada et al., 2020). Schools need to be open to educational innovations, both in terms of content and methodologies (Hirdes et al., 2006). In general, teachers are responsible for bringing this (Jong, 2019) and, in addition, it is extremely urgent to recognize the potential of digital technologies (DT) in the educational context, resulting in different opportunities for students and expanding the limits of the classroom (Gabini & Silva Diniz, 2009; Henderson, Selwyn & Aston, 2017). According to the Instituto Brasileiro de Geografia e Estatística (IBGE, 2023), it is estimated that 92.1% of the Brazilian population has frequent access to the Internet. According to the Continuous National Household Sample Survey (IBGE, 2022), 92.2% of students had used the internet in the last 3 months, compared to 85.9% of the general population. However, when considering the education system, there is a difference in usage. In the private system, the rate was 98.4%, while in the public system it was 84.0%. However, data collected during the COVID-19 pandemic showed that less than half of students enrolled in the public school system, in several states, had access to virtual classes (IBGE, 2021). Therefore, it is important that these data be taken into account when planning activities in which a survey of each student's reality is carried out.

Students use the DTs that are convenient for them to access audiovisual materials, which is why we use a smartphone to produce the videos. These DTs act as mediators of the teaching and learning process, access and sharing of information have intensified through the digital environment, in addition to breaking the local and temporal barriers of a classroom (Nichele, 2016). There are numerous channels on YouTube® related to basic education, including chemistry teaching, but a recurring complaint from students is related to the length of the videos, which are mostly long. This is similar to what happens in the flipped classroom, where the challenge is mainly related to the length of the videos (Al-Samarraie, Shamsuddin & Alzahrani, 2020). GenZ is commonly described as instantaneous and has a faster pace of life; however, these characteristics are not necessarily a problem, in fact, they can be seen as a positive effect of Web 2.0 (Persada et al., 2020). Thus, it is believed that the production of short videos is an attractive and efficient way to approach concepts. Even if it is possible to pause a long video until the desired part is found, the demand for time and patience is high, often causing students to give up watching the entire video.

Preparation for the development and application of the educational product

The stages of development and implementation (The complete educational product can be accessed via the link: http://hdl.handle.net/10183/218101) are described below.

1. Application of an initial questionnaire on the perception of the stoichiometry content for 64 students and graduates of a high school in the metropolitan region of Porto Alegre;
2. Creation and application of a list of stoichiometry problems (Table 1);
3. Creation of a channel with a video list of solutions and access to the channel for students;
4. Creation and application of a list of exercises similar to the first one (Table 2) after watching the videos;
5. Questionnaire on the students' perception of the educational product.

Initial questionnaire

The questionnaire entitled “Evaluation of students’ perception of stoichiometry content” was conducted with the aim of seeking possible indicators regarding the difficulties presented, or not, in the stoichiometry content developed during high school, in the Chemistry discipline. This questionnaire was prepared through the Google Forms platform and was made available to students (53) in the 11th grade, 12th grade and (40) concluded, from a private school located in a city in the Metropolitan Region of Porto Alegre, through the WhatsApp application. The questionnaire contained fifteen objective questions, three discursive questions and two questions in which it is possible to choose more than one answer and was answered by 64 students. The objective was to verify (i) which points of greatest difficulty regarding the content, (ii) which tools they usually use, (iii) which tools they believe are most effective for better learning the stoichiometry content and (iv) which resources they usually use to study outside the classroom. Questions 2 to 12, as well as 14 and 15 were presented using the 5-points Likert scale [1 - Strongly Disagree], [2 - Disagree], [3 - Neutral], [4 - Agree] and [5 - Strongly Agree] as are described below:

1) What is your education level?
    a) 11th grade
    b) 12th grade
    c) Concluded
2) Amongst all the high school Chemistry content, the one I consider the most difficult to learn was stoichiometry.
3) I found it easy to solve questions involving stoichiometry during high school.
4) When solving stoichiometry questions, I had difficulty interpreting the statement. Why?
5) When solving stoichiometry questions, I had difficulty balancing the chemical equation provided.
6) When solving stoichiometry questions, I had difficulty writing the chemical equation when it is not provided. Why?
7) When solving stoichiometry questions, I had difficulty identifying the data provided by the statement. Why?
8) When solving stoichiometry questions, I had difficulty performing the necessary unit conversions.
9) When solving stoichiometry questions, I had difficulty converting moles to mass.
10) When solving stoichiometry questions, I had difficulty converting moles to molecules.
11) When solving stoichiometry questions, I had difficulty converting moles to atoms.
12) When solving stoichiometry questions, I had difficulty converting moles to volume.
13) I am aware that I can relate other units of measurement that do not involve only moles.
    a) I agree
    b) I disagree

14) When solving stoichiometry questions, I had difficulty setting up the rule of three.
15) When solving stoichiometry questions, I had difficulty solving the rule of three mathematically.
16) What would be a possible solution for learning stoichiometry?
    a) Mobile app
    b) Mobile games
    c) Computer games
    d) Short videos on YouTube
    e) Handouts
    f) Extra in-person classes with the teacher
    g) Extra online classes with the teacher
17) How do you usually study, in general?
    a) I read about the content in a book or handout.
    b) I read about the content in materials available on the internet.
    c) I watch videos on YouTube about the subject.
    d) I do exercises with some physical material such as a book or handout.
    e) I do exercises with some material available on the internet. I just watched my teacher's class.
    f) I make summaries.

Preparation of the educational product

Based on the results obtained in the initial questionnaire, an educational product was chosen that was in line with the most voted item “short videos on YouTube” (as can see in Figure 3) as a possible solution to improve the learning of stoichiometry. The videos were recorded using a smartphone, using a spotlight and a tripod-shaped support for the smartphone (Figure 1). The audio was captured at the time of recording the videos using the smartphone's own headphones.

Figure 1

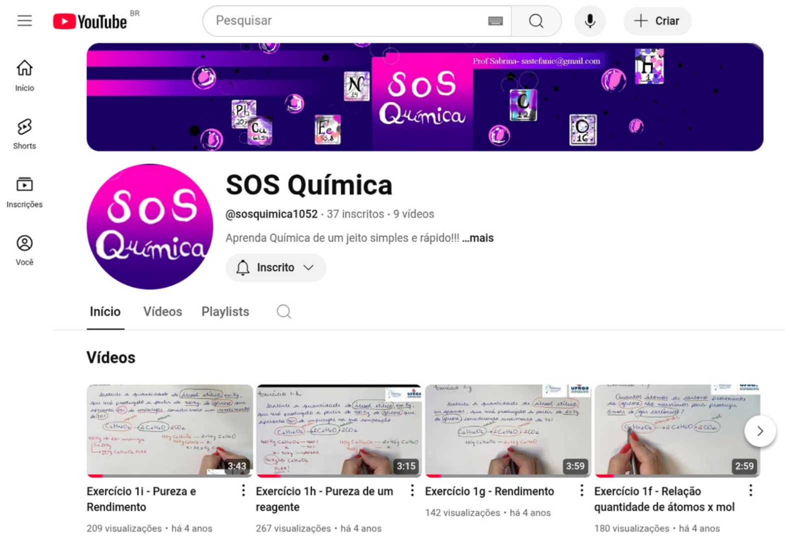
Equipment used to record the videos.

Source: From our own authorship (2024).

Thus, the “SOS Química” Channel[1] was created on YouTube® (Figure 2) to disseminate the videos, since videos with exercise resolutions on social media have been pointed out as a tool used by students (Rospigliosi, 2019; Hight, Nguyen & Su, 2021).

Figure 2

View of the home page of the “SOS Química” channel.



Source: From our own authorship (2024).

The resolutions were recorded in landscape mode, in which only the teacher's hand will be visible, with the aim of focusing the student's attention entirely on solving the exercise. In addition, colored pens were used to highlight the different information, such as balancing, extra calculations, molar masses of the substances and the rule of three itself. The videos were edited using the free version of the Wondershare Filmora 9 application. After recording, the videos were edited and made available on YouTube® on the Channel “SOS Química”.

The list of exercises on stoichiometry was carefully prepared in order to overcome the main learning difficulties related to the literature in the area of chemistry teaching: understanding the languages of chemistry, physics and mathematics (Le Marie et al., 2018) and reading comprehension. These difficulties affect the learning of sciences, which derives from a network of knowledge of which reading ability is a part. Reading that does not promote understanding of the information poses an obstacle to scientific literacy (Sanmartí, 2010). Based on the teaching experience of the researchers in the high school, it was possible to observe that the longer the statement, the lower the correct answer rate for the question. This perception is corroborated by researchers in chemistry teaching who describe that reading the statements requires reading comprehension to correctly identify the chemical substances, quantities and proportions presented for the correct assembly of the chemical equation and its respective balancing. In the planning stage, it is necessary to configure mathematical procedures based on the interpretation of the statement to finally perform the calculations (Cotes & Cotuá, 2014; González-Sánchez et al., 2014). For these reasons, the list consists of a single chemical equation, which represents the fermentation of glucose into ethanol and carbon dioxide, and from this, questions were created that involved relationships between mass, number of moles, quantity of molecules, etc. (see Table 1). Initially, the students solved this list (List 1). Afterwards, they received a copy of the solution so that they could correct the List 1 by watching the videos on the Channel. This same list is on the channel in the form of a playlist organized to develop the calculations stated in Table 1, starting from the following problem: Answer the questions regarding glucose fermentation occurring according to the following balanced equation:

$$C_6H_{12}O_6 \rightleftharpoons 2C_2H_6O + 2CO_2$$

Table 1

Stoichiometric calculations of List 1 and Channel video list.

Questions	Link	Relationship
How much ethyl alcohol, in grams, will be produced from the fermentation of 18 kg of glucose?	https://youtu.be/X3AxBnMt57o	Mass x mass ratio
How many moles of carbon dioxide will be produced from the fermentation of 15 moles of glucose?	https://youtu.be/Rvar-ZQLzl8	Mole x mole ratio
How much glucose, in kg, is needed to produce 700 kg of ethyl alcohol?	https://youtu.be/Lci3TnmozDg	Mass x mass ratio
What mass of glucose is needed to produce 15 moles of ethanol?	https://youtu.be/LKxDHtr_xj8	Mass x mole ratio
How many molecules of carbon dioxide are produced from 180 kg of glucose?	https://youtu.be/7e_73-4aYWY	molecules x mass ratio
How many carbon atoms from glucose are needed to produce 5 moles of carbon dioxide?	https://youtu.be/Wz4gTe5v6EQ	atoms x mol ratio
Calculate the amount of ethyl alcohol, in grams, that will be produced from 25 kg of glucose, considering a yield of 75%.	https://youtu.be/kbP_VK26PVw	Yield
Calculate the amount of ethyl alcohol, in kg, that will be produced from 50 kg of glucose that has 10% impurities in its composition.	https://youtu.be/A87Wn0o2Feg	Purity
Calculate the amount of ethyl alcohol, in kg, that will be produced from 100 kg of glucose that has 25% impurities, considering a yield of 80%.	https://youtu.be/G5LnwjH6148	Yield and Purity

Source: From our own authorship (2024).

After solving the List 1 and watching the video list, a new list was applied (presented in Table 2) with the question "Answer the questions regarding the combustion of ethanol (ethyl alcohol) according to the balanced equation below:"

$$C_2H_6O + 3O_2 \rightleftharpoons 2CO_2 + 3H_2O$$

Table 2

Stoichiometric calculations of List 2.

Questions	Relationship
How much ethyl alcohol, in grams, will be needed to produce 88 kg of carbon dioxide?	Mass x mass ratio
How many moles of water will be produced from the combustion of 12 moles of ethanol?	Mole x mole ratio
What mass of ethanol is needed to produce 15 moles of carbon dioxide?	Mass x mole ratio
How many molecules of carbon dioxide are produced from 60 kg of ethanol?	molecules x mass ratio
How many carbon atoms from ethanol are needed to produce 5 moles of carbon dioxide?	atoms x mass ratio
Calculate the amount of carbon dioxide, in grams, that will be produced from 10 kg of ethanol, considering a yield of 85%.	Yield
Calculate the amount of water, in kg, that will be produced from 50 kg of ethanol that has 20% impurities in its composition.	Purity

Source: From our own authorship (2024).

Questionnaire on perceptions of the educational product

After completing the List 2, students received a questionnaire for evaluation, containing the following questions, with questions 1 to 5 on a 5-point Likert scale: [1 - Strongly Disagree], [2 - Disagree], [3 - Neutral], [4 - Agree] and [5 - Strongly Agree].

1) The videos are presented in clear and easy-to-understand language.
2) The videos present concepts that I did not know or did not remember.
3) The exercises solved in the videos helped me understand the concepts.
4) I was able to solve most of the exercises without difficulty.
5) The material (list of exercises and videos) helped me better understand the content of the subject.
6) Mark the topic that was easiest for you:
    a) Relationship between mass and mass
    b) Relationship between mole and mass
    c) Relationship between mole and mole
    d) Relationship between mass and molecules
    e) Relationship between mass and atoms
7) Mark the topic that was most difficult:
    a) Relationship between mass and mass

b) Relationship between mole and mass
c) Relationship between mole and mole
d) Relationship between mass and molecules
e) Relationship between mass and atoms

8) Mark the topic that was most difficult:
   a) Purity of a reagent
   b) Reaction yield
   c) Both when they appear in the same question
9) At the end of the entire process, did I have a satisfactory performance in the stoichiometry content?
   a) Yes b) No

Results and Discussions

Questionnaire with students to identify difficulties and possible tools

The results obtained with this questionnaire "Evaluation of students' perception of stoichiometry content", answered by 64 students, which aimed to evaluate students' perception of stoichiometry content, showed that among all the content studied by them, stoichiometry is seen by the majority as being the most difficult. For example, for the question: "Amongst all the Chemistry content in high school, the one I consider the most difficult was stoichiometry", 45.3% of the votes were for [3 - Agree] and 10.9% for [4 - Fully Agree]. This result is in line with the experiences lived by teachers in the classroom and with research that addresses this topic. For the question "When solving stoichiometry questions, I had difficulty interpreting the statement", alternative [3 - Agree] received 50% of the votes and [4 - Fully Agree] another 25%, indicating that the vast majority of students report difficulties in solving stoichiometry questions. Analyzing the answers provided, for the questions we can categorize three main reasons for the difficulties in stoichiometry: problems with reading comprehension, understanding of chemical language and understanding of mathematics and physics language.

1. Problems with reading comprehension

Reading the statements requires reading comprehension skills so that one can correctly identify the chemical substances, the quantities and proportions presented, and the types of quantities involved in assembling the chemical equation, as well as their respective balancing of the chemical equation and assembly of the calculation to be performed (Cotes & Cotuá, 2014; González-Sánchez et al., 2014). When analyzing the students' written productions (Table 3), it was possible to clearly identify the relationship established with the reading comprehension skill.

Table 3

Excerpts from responses categorized as reading comprehension difficulties.

Student	Statement
Student 11	Because I do not clearly understand, what the question is asking.
Student 12	It is often difficult to understand what the exercise really wants, but I always follow an order which makes it easier, after all the exercises have a pattern.
Student 40	I believe it is more of a personal issue regarding ease. For me, the calculations are easier to understand than the interpretation part in Portuguese.
Student 38	Because, in some questions, the statement contains many useless data that ends up being confused with the necessary data.
Student 40	In general, I believe that the data is very specific and when it is not, I end up making mistakes due to the interpretation.
Student 42	Because most statements contain unnecessary information that complicates things and leads us into error.
Student 43	Because the statement was the most difficult part of putting the question into practice.
Student 48	In some statements, yes, because I am not very good at interpretation. My biggest difficulty is getting the thread of the story, and then I can do it. Sometimes I get confused, but I think I am managing to deal with it better.
Student 51	Because I understood the statement, but I could not formulate the calculation based on it.
Student 26	Sometimes it is hard to know where to start.
Student 31	Due to lack of interpretation, this was always the biggest difficulty after I managed to put it on paper, then everything worked out fine.

Source: From our own authorship (2024).

The main findings indicate that, in the students' view, the statements can be confusing, extensive and contain unnecessary information, making it difficult to understand the problem to be solved. Some consider that the statement may not provide sufficient information about the reaction, such as the reagents involved, the products formed or the reaction conditions, which makes it difficult to write the equation. There is mention of the difficulty in relating the data in the statement to the concepts of stoichiometry and the calculations necessary for the solution. In other words, the ability to identify which information in the statement is relevant to the problem and which can be discarded is crucial for successful resolution. However, students confuse this with "too much information" or the presence of "unnecessary information". In fact, an elaborate statement can confuse students and divert them from the data relevant to solving the problem. However, some students admit to inattention when reading the statement, which can lead to misinterpretation of the information and the loss of important data.

2. Understanding of chemical language

The lack of understanding of chemical language and basic concepts, as well as alternative conceptions about chemical reactions (Batinga & Teixeira, 2014) can contribute to the difficulty in solving problems. Likewise, a mathematical focus to the detriment of a chemical interpretation, which can lead to a mechanization of problem-solving procedures (Costa & Souza, 2013).

The difficulty of abstraction and transition between levels of representation of matter; the lack of understanding of Avogadro's number, the lack of understanding of the concepts of quantity of matter and mole, in particular, can be related to the confusion of the terms mole, molecule, molar, as well as the confusion between the use of indexes and coefficients (Sanger, 2005). All of these factors influence the ability to set up equations and perform the correct balancing so that it is possible to solve stoichiometric calculations. By analyzing the students' written productions (Table 4), it was possible to extract excerpts that represent the difficulties pointed out with chemical language.

Table 4

Excerpts from responses categorized as difficulty in chemical language.

Student	Statement
Student 6	I have difficulty setting up the equation when it is not ready. I also have difficulty when the exercise asks for data that is contrary to what we are used to solving.
Student 3	The basic contents of chemistry were not completely learned and assimilated.
Student 6	Sometimes the question gives the popular name of the substance and not the chemical name, where we know the union of the cation + anion from the table.
Student 16	It is necessary to remember past content, but again, after doing more exercises I was remembering.
Student 20	Because I sometimes had difficulties with the elements of the equation that were not present in the statement, but are intrinsic to that particular reaction.
Student 33	It is boring to memorize formulas and their names.
Student 40	At the beginning of the study, in the first year, the chemical equation did not make sense to me if it was not for the formation of a salt, but after understanding more about how the formation of other substances worked, everything became quite easy, it was a matter of studying and understanding several examples.
Student 62	Because the nomenclature of some compounds is different from the standard nomenclature established by IUPAC or I just forgot and/or got confused.
Student 1	I found it very difficult to understand exactly what the question wanted, the proportions, the units of measurement, etc.
Student 57	Difficulties with nomenclature and making the drawing.
Student 30	Sometimes some statements have a lot of information and data, and

	this ends up confusing me and I often do not know which one to use.
Student 20	Because most of them were easy to interpret, if the statement was read carefully.

Source: From our own authorship (2024).

We can highlight in this category the difficulty in identifying and interpreting the nomenclature of substances and the units of measurement used in the statements; it is also a frequent point for students to report difficulty in remembering the chemical formulas of the compounds and in associating them with their usual or popular names, which prevents the correct writing of the equation. This lack of knowledge of chemical nomenclature can make it difficult to identify the compounds mentioned in the statement and, consequently, the data related to them. From the student's perspective, the chemical nomenclature of inorganic compounds includes a series of complex rules and situations that involve unknown concepts, such as oxidation states of transition metals and polyatomic ions (Wirtz, Kaufmann & Hawley, 2006).

3. Understanding of mathematics and physics language

The lack of a mathematical basis and the difficulties in handling mathematical techniques (Costa & Souza, 2013, Santos & Silva, 2014) impact the skills of solving stoichiometric problems and, associated with chemical language, bring a complexity of their own that can prevent students from using simple mathematical operations to solve them (Le Marie et al., 2018). In addition to the difficulty with the physical language referring to the different quantities used in solving stoichiometric problems, it is evident that students often memorize the formulas and definitions, without understanding the underlying concepts necessary to work with abstract units of measurement (Marais & Combrinck, 2009). As an example, we can mention the concept of mole or quantity of matter (Fang, Hart & Clarke, 2014) and calculations involving Avogadro's constant (Pekdağ & Azizoğlu, 2013), which are issues reported in several researchers. Cárdenas & Antonio (2006) highlight the overload of instructions in working memory and insufficient familiarity with the basic operations necessary to solve the problem. The excerpts contained in Table 5 translate these difficulties pointed out in the literature regarding mathematical and physical language.

Table 5

Excerpts from answers categorized as difficulties in mathematical and physical language.

Student	Statement
Student 4	Relate different data in different units and interpret why each data should be used in the calculation.
Student 1	I found it very difficult to understand exactly what the question wanted, the proportions, the units of measurement, etc.
Student 10	Sometimes I get the information mixed up and have trouble putting together the rule of three.
Student 7	I have difficulty with interpretation in general, but sometimes I get confused with the nomenclature of a certain substance or units of measurement.

Student 22	Some statements are not so clear, in terms of substances, units, etc.
Student 34	Errors are more common when making calculations.
Student 55	I had difficulty relating the statement to the calculations needed to resolve the problem.

Source: From our own authorship (2024).

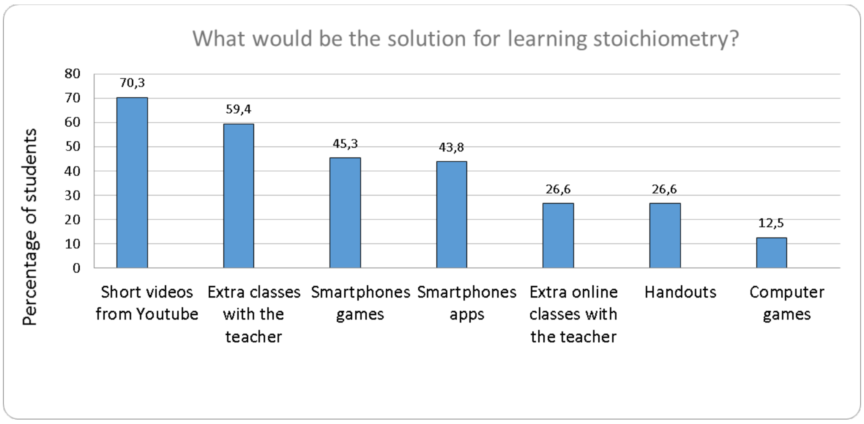
In this category, we highlight the difficulty identified regarding the translation of the information in the statement into a mathematical language appropriate for solving the problem. In addition, the lack of mastery of basic mathematical operations is observed, and knowing how to manipulate chemical equations are essential skills for solving stoichiometry problems. There is also mention of the difficulty in interpreting units of measurement, resulting from the lack of familiarity with the units of measurement that can lead to confusion and difficulty in manipulating the quantities correctly. In the excerpts written by the students, we observe the lack of mastery of concepts such as molar mass, mole, which can make it difficult to identify the data that represent these quantities in the statement and can lead to confusion and difficulty in identifying the relevant data.

Students' views on possible ways to overcome difficulties and possible tool

When asked what would be a possible solution for learning stoichiometry, the option "short videos on YouTube®" received the highest number of responses, as can be seen in Figure 3, followed by extra classes with the teacher, which, unfortunately, is difficult to carry out within the reality of Brazilian education. Games and smartphone applications appear next, demonstrating the importance of digital media for the learning of high school students today. In addition to being a valuable teaching resource for basic education students, who are digital natives.

Figure 3

Possible solutions to improve learning in stoichiometry.

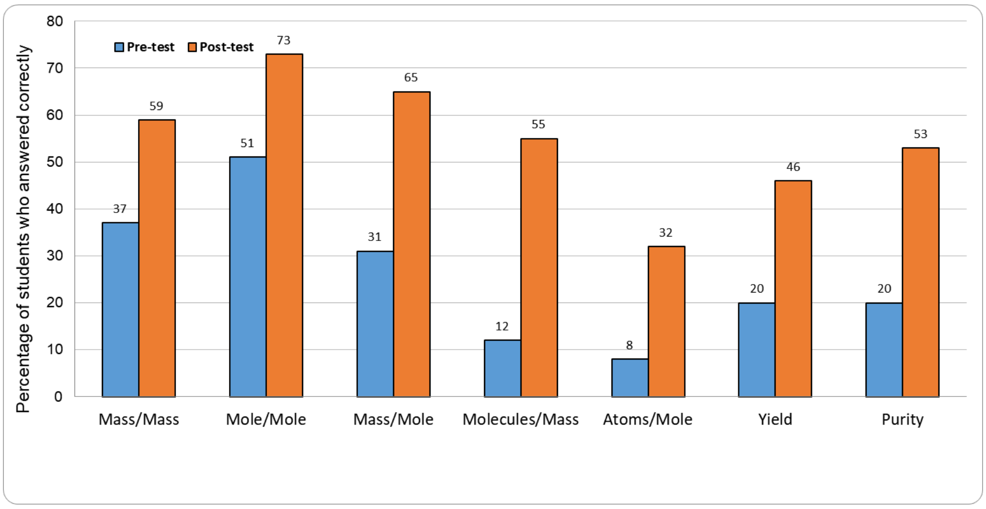


Source: From our own authorship (2024).

We evaluated the educational product by means of a comparative analysis between the performance in the pre- and post-questionnaire questions. Figure 4 shows the results before and after the application of the videos, and the difference between them is notable. The resolutions of the videos were essential to improve the results in the exercises applied later.

Figure 4

Percentage of correct answers for each question on the list before and after watching the videos.



Source: From our own authorship (2024).

In general, for questions about the relationships between reaction quantity quantities (see the last column of Table 1 for the complete relationship), more than 60% of students indicated that they had no difficulty converting units, for the question “When solving stoichiometry questions, I had difficulty converting moles to atoms.” Alternative [4-Agree] received 54.7% of the votes and [5-Strongly Agree] another 9.4%, indicating that the quantity of molecules and atoms of the substances in the reaction is a difficulty for students.

Educational Product Evaluation Questionnaire

A questionnaire with five questions using the Likert scale [1-Strongly Disagree], [2-Disagree], [3-Neutral], [4-Agree] and [5-Strongly Agree] as well as four multiple-choice questions was applied to the students who participated in the previous stage, and was answered by 38 students in the first year of high school.

Initially, for the statement “The videos present clear and easy-to-understand language”, all students agreed and marked 4 (23.7%) and 5 (78.3%) as the answer on the Likert scale, clearly indicating that the language of the videos was easy to understand for all students. As for the statement “The videos present concepts that I did not know or did not remember”, the answers were 28.9%; 7.9%; 10.5%; 42.1% and 10.5%; respectively for the Likert scales from 1 to 5, demonstrating that more than half of the students agree with this statement. Regarding the role of the video list, all students scored 4 (23.7%) or 5 (76.3%) on the Likert scale for the statement “The exercises solved on video helped in understanding the concepts”, indicating that the videos helped in solving the exercises. Regarding the multiple-choice questions, the mass/atom and mass/molecule relationships (see the last column of Table 1 for the complete list) each received 36.8% when asked which presented the greatest difficulty, indicating that the transformation between mass and the number of entities participating in the reaction are the main difficulties. Thus, most students agree that the videos have accessible language and that they helped to understand the concepts of stoichiometry. The use of this material facilitated the learning process for students, as they themselves reported in the questionnaire applied at the end of the entire process. Specifically in the question “The material (list of exercises and videos) helped me to better understand the content of the subject”, more than 90% of students agreed that the material contributed to a better understanding of the stoichiometry content.

Final Considerations

The present study aimed to address the difficulties in learning stoichiometry concepts and to develop an educational product to help overcome such difficulties. The analysis of the preliminary results indicates that the students' difficulties are mainly related to the interpretation of the statements and the lack of mastery of the languages of chemistry, physics and mathematics. Such difficulties are similar to those that have been pointed out by researchers in the area of chemistry teaching over the years.

Based on these considerations, we present the development and application of an educational product in the format of a YouTube channel with video lists for solving problems in stoichiometry, since this type of resource was indicated by the group of students as the most used for extracurricular studies. The results obtained indicated advances in the students' learning process, both when we analyzed the performance in List 1 (pre-application of the educational product) and List 2 (post-application of the educational product), and by evaluating the perception of the educational product. Suggestions for teachers who aim to develop other teaching strategies to overcome difficulties in the classroom regarding this concept include: Dedicating time to activities to review basic concepts. Investing in the development of statements with greater clarity. Using exercises with varied statements, contextualized problems, and activities that promote data analysis and interpretation can help students develop this skill. Exploring different problem-solving methods can help them find the strategy that best suits their learning style.

In addition, it is worth noting that, in the current sociocultural context, it is imperative to invest in the development of teaching proposals that aim to use digital technologies that can promote better learning of scientific concepts, taking into account the characteristics of GenZ and future generations.

NOTES

1. https://www.youtube.com/@sosquimica1052

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